Reply to comment on parton distributions, d/u, and higher twist effects at high x

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M. Melnitchouk *et al.* [1] misunderstand the model of Frankfurt and Strikman [2] for nuclear binding effects in deep inelastic scattering (DIS). In addition, their comment is entirely irrelevant to the results of our article.

In the Frankfurt-Strikman model the main parameter used to describe the deviations of the structure functions of bound nucleons from those of free nucleons is the average kinetic energy of the nucleons in the nucleus, with small corrections due to energy binding (the parameter is $k^2/2m + \epsilon_A$, where k is nucleon momentum and ϵ_A is energy binding per nucleon ($\epsilon_{A\sim 200} \approx 8MeV$). If the value of x is not too large (below $x = 0.75$) the binding effects are proportional to the average value $\langle k^2 \rangle /2m+\epsilon_A$. For heavy nuclei one can safely approximate the resulting A-dependence of the binding effects in terms of the A- dependence of $\langle k^2 \rangle /2m$. Note that the Fermi motion effects are also proportional to average value of k^2 in this x-range. Frankfurt and Strikman also argue [2] that a similar pattern is valid in a wide range of models including pion models and the so called nuclear binding models where the large x depletion of the nuclear structure functions is from a reduction of the light-cone momentum fraction carried by nucleons. Hence the overall deviation from 1 of the ratio of the nuclear structure functions to that of free nucleons ($R_A(x) - 1$) is a factorized function of $\phi(A) * f(x, Q^2)$. An estimate of the overall scale of $\phi(A)$ and the function $f(x, Q^2)$ can be extracted from the SLAC data on heavy targets. It is well known that in mean field nuclear models, $\langle k^2 \rangle /2m$ is proportional to the average nuclear density (this is also approximately valid for $\langle k^2 \rangle /2m + \epsilon_A$). The nuclear density fit gives a good description of the SLAC data [3].

We have used the SLAC nuclear density fit to get the effects of the nucleon binding in the deuteron on the structure functions. The SLAC fit implies that the effects in the deuteron are about 25% of the effects in iron. For comparison, Frankfurt and Strikman [2] calculate the following ratio for the relevant quantity in iron and deuterium $\frac{\langle k^2 \rangle_{Fe} + \epsilon_{Fe}}{\langle k^2 \rangle_D + \epsilon_D} \approx 5$. From this ratio, they extract the relation $(F_{2D}/F_{2N} - 1) = 0.25(F_{2Fe}/F_{2D} - 1)$, which is close to the value used in our paper. Therefore, although the notion of nuclear density for the deuteron may not be very well defined, the value of the nuclear density for deuterium that was used in the SLAC fit yields a similar correction for nuclear binding in the deuteron as the estimate by Frankfurt and Strikman. Note that the the uncertainty in the value of 0.25 is about 20%, and that the x-dependence is well constrained by the $A \geq 4$ data.

Figure 1 of our paper shows that the nuclear binding effects in deuterium as estimated from the nuclear density (solid line) are actually almost identical to the model of Melnitchouk and Thomas [4] (dashed line) in the region of $x = 0.6$. Therefore, all three models for for the nuclear binding corrections to the structure functions in the deuteron, namely the SLAC nuclear density fit, the Frankfurt and Strikman model, and the Melnitchouk and Thomas model are all in agreement with the corrections that are used in our paper at large x. The proportionality of the nuclear binding corrections to the average kinetic energy k^2 is pretty generic and hence holds in the model of Melnitchouk and Thomas as well. When one averages over nucleon momenta one ends up with a similar combination of kinetic energy and energy binding for their model also.

However, the predictions from the Melnitchouk and Thomas model (which so far has not been applied to $A \geq 4$ nuclei) show large binding effects in deuterium at $x = 0.3$, where there is no difference between the structure functions of iron and deuterium. At $x = 0.2$, the model predicts binding effects in deuterium which are of opposite sign to that in iron. These strange features of the Melnitchouk-Thomas model are the reasons why we did not use that model in the extraction of neutron structure functions from deuterium data. The strange features of their model at lower x are likely to originate from the fact the energy momentum sum rule is not satisfied in their theory. A resolution of this problem and tests of the model for heavy nuclei are needed.

If light nuclei like ^{3}He, ^{3}H are considered, the original formulae of Frankfurt and Strikman in terms of k and ϵ (with realistic models of the A=3 wave functions) should be used. Here also, there is great advantage of relating the nuclear binding effects in a light nucleus to the experimental ratio of the binding effects in iron and deuterium. Within such a framework, the energy momentum sum rules are satisfied, and the models can be used over a larger range of x.

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[3] J. Gomez *et al.*, Phys. Rev. D**49**, 4348 (1994).
[4] M. Melnitchouk and A. W. Thomas, Phys. Lett. B**377**, 11 (1998)